Constraining the range of climate sensitivity through the diagnosis of cloud regimes

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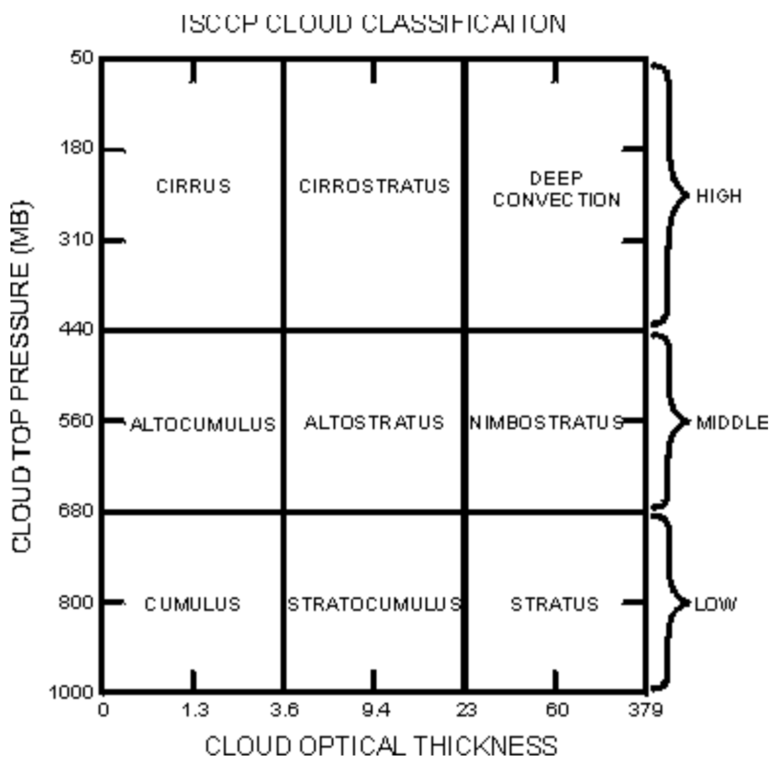
Background

- Much of the variation in the climate sensitivity between GCMs is due to differing radiative feedback from clouds.
- Can aspects of the present-day climate be used to provide an evaluation of GCMs which will constrain the range of climate sensitivity?
- Many types of evaluation have been proposed for GCMs, however very few have been demonstrated to significantly/tightly constrain the range of climate sensitivity.

Identification of cloud regimes



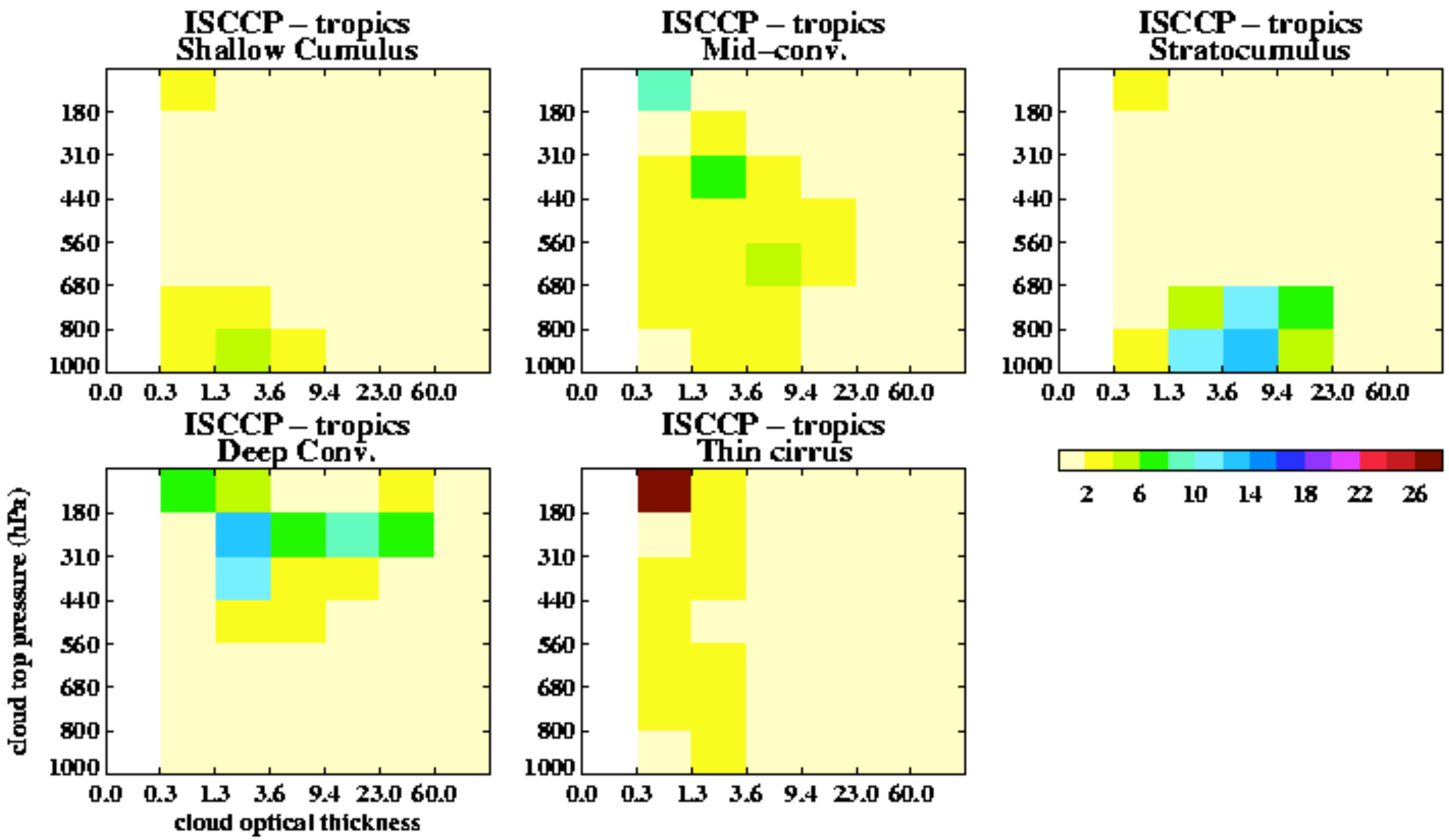
•The method uses a daily mean ISCCP cloud amount histograms from each grid-point for 5-years worth of data (from observations and present-day and 2xCO_2 simulations from GCMs).

•A clustering algorithm is applied to each experiment to effectively group together spatio-temporal grid points with similar cloud top pressure, cloud optical depth and fractional total cloud coverage of the grid-box (following Jakob and Tselioudis, 2003).

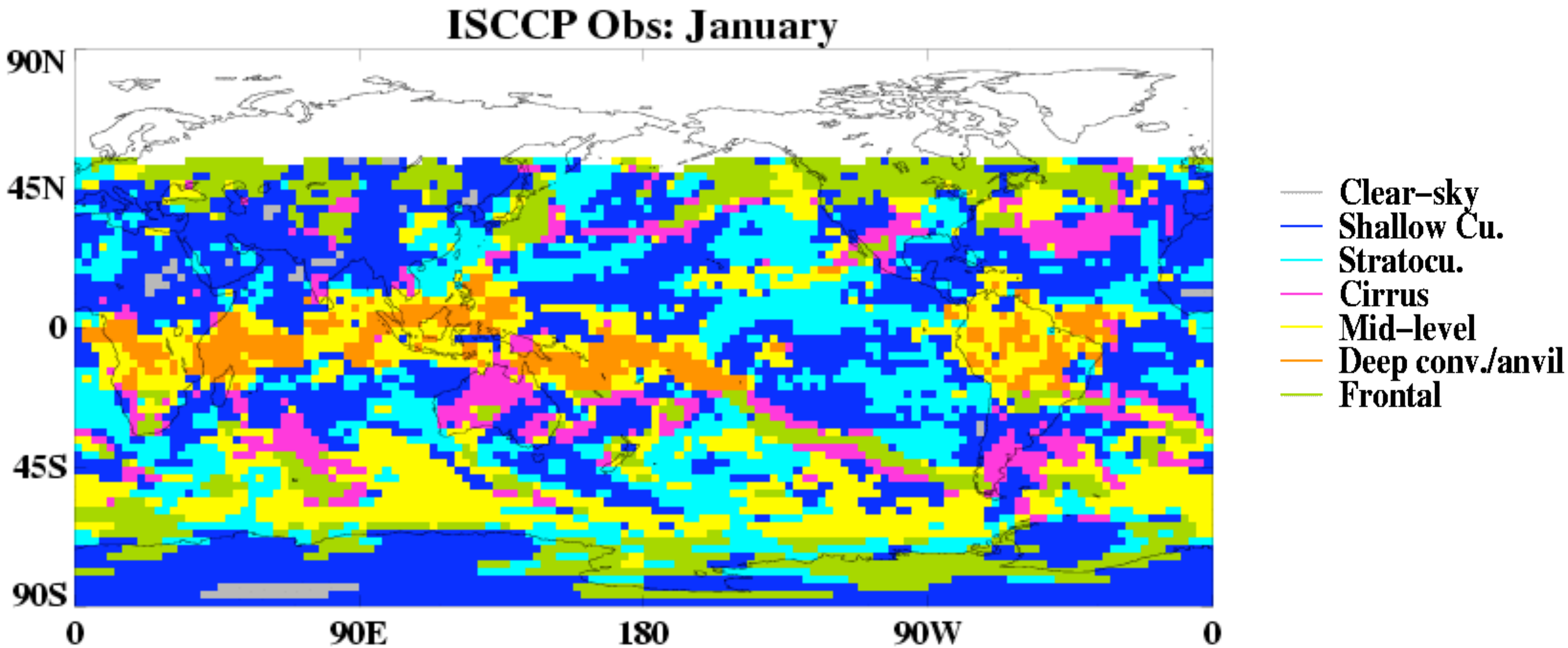
•Several of the resulting clusters are subjectively combined to provide a small set of common cloud regimes from the model and observations.

•The tropics (20N-20S) and the snow/ice-free extra-tropics (polewards of 20N/S) are considered separately.

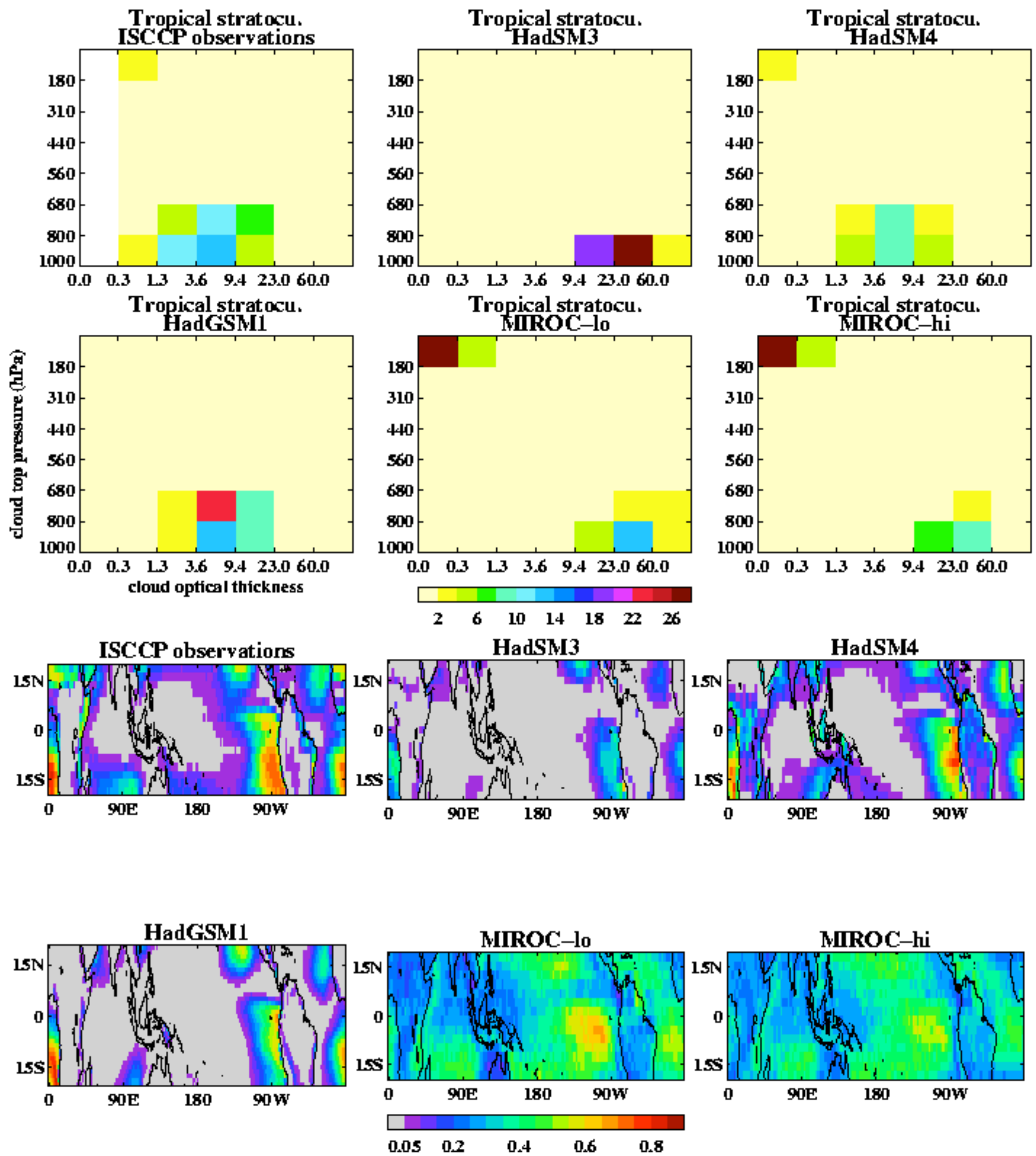
ISCCP observational cloud regimes (Tropics)



ISCCP cluster location



GCM simulated tropical stratocumulus regime



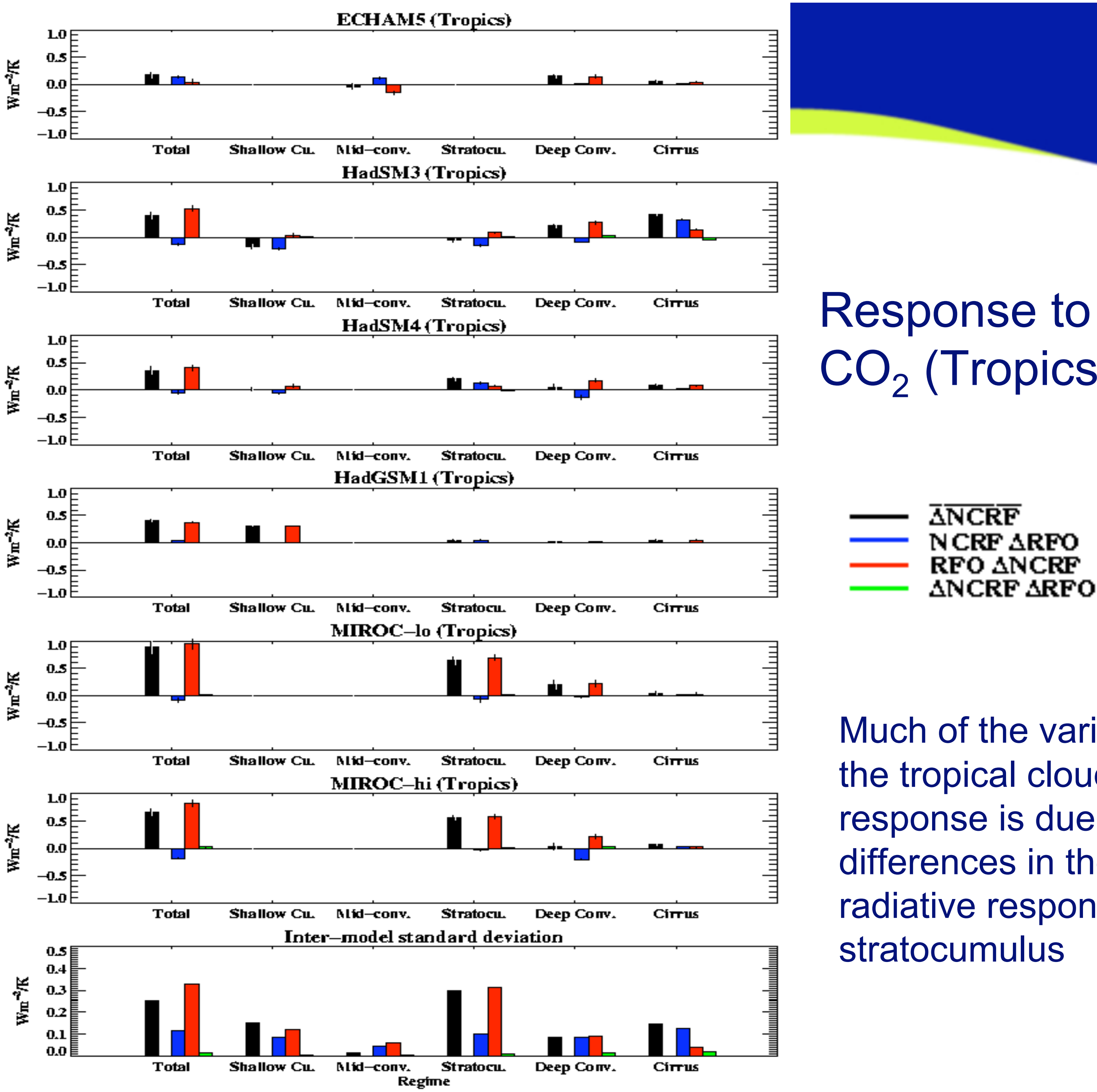
Climate change response

In the cloud regime framework, the mean change in cloud radiative forcing can be thought of as having contributions from:

•A change in the RFO (Relative Frequency of Occurrence) of the regime

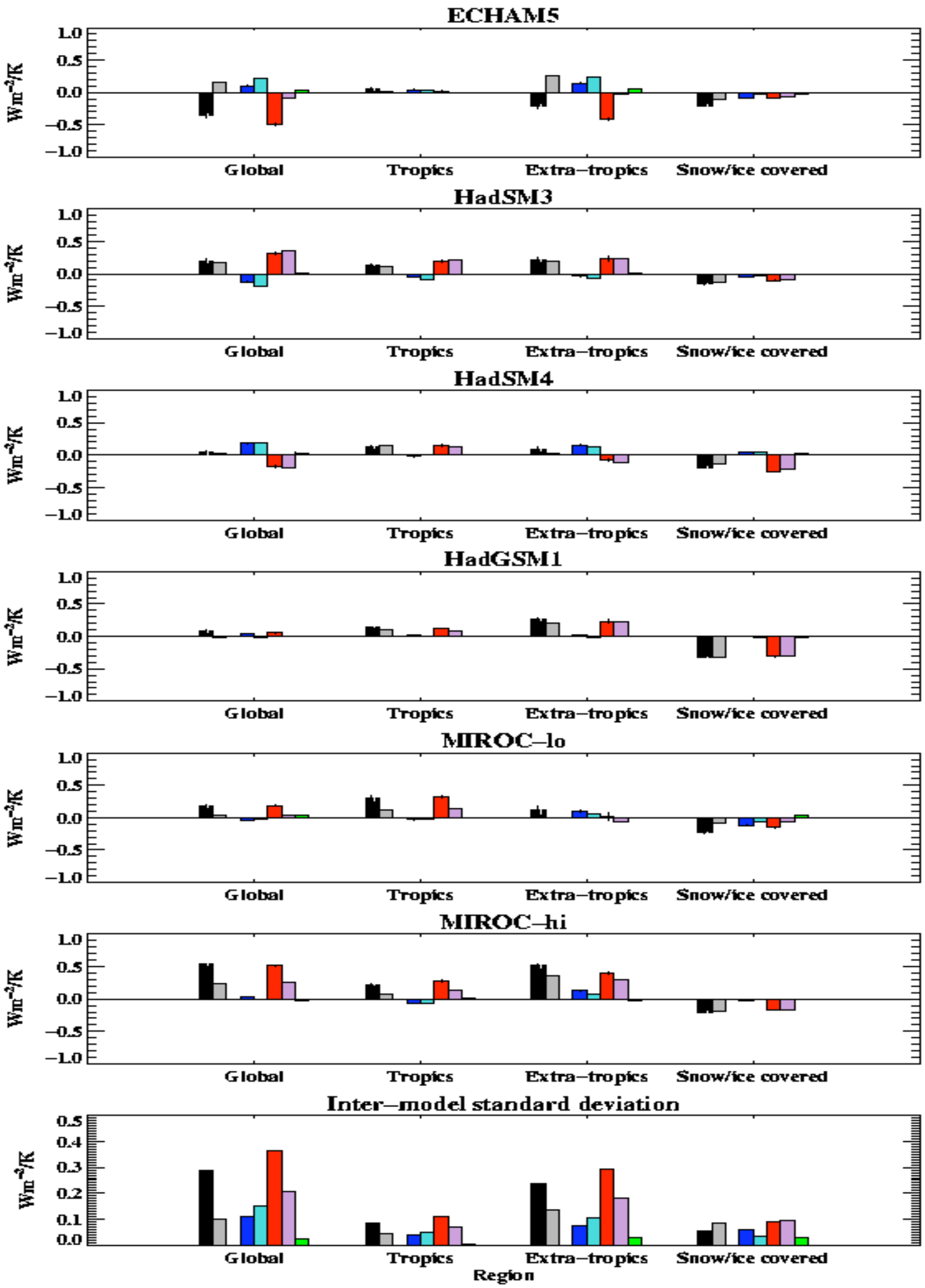
•A change in the CRF (Cloud Radiative Forcing) within the regime (i.e. a change in the tau-CTP space occupied by the regime/development of different clusters).

$$\overline{\Delta CRF} = \sum_{r=1}^{nclusters} CRF_r \, \Delta RFO_r + \sum_{r=1}^{nclusters} RFO_r \, \Delta CRF_r + \sum_{r=1}^{nclusters} \Delta RFO_r \, \Delta CRF_r$$



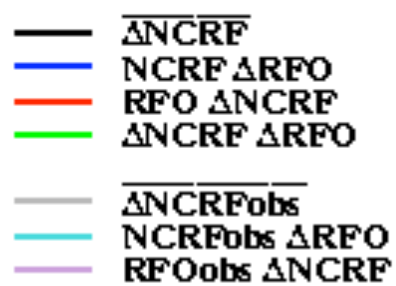
Response to doubling CO_2 (Tropics)

Much of the variation in the tropical cloud response is due to differences in the radiative response of stratocumulus



Global cloud response to $2xCO_2$

$$\overline{\Delta CRF} = \sum_{i=1}^{nclusters} CRF_i \, \Delta RFO_i + \sum_{i=1}^{nclusters} RFO_i \, \Delta CRF_i + \sum_{i=1}^{nclusters} \Delta RFO_i \, \Delta CRF_i$$



Potential to constrain the range of climate sensitivity

Model	Difference in $\overline{\Delta NCRF}$ (Wm^{-2}/K)	Model λ (Wm^{-2}/K)	Obs. constr. λ (Wm^{-2}/K)	Model clim. Sens. (K)	Obs. constr. Clim. Sens. (K)
ECHAM5	0.49	1.21	0.72	3.3	5.6
HadSM3	0.17	1.06	0.89	3.5	4.2
HadSM4	0.03	1.00	0.97	3.7	3.8
HadGSM1	-0.11	0.83	0.94	4.6	4.1
MIROC-lo	-0.12	0.79	0.91	3.9	3.4
MIROC-hi	-0.19	0.48	0.67	6.5	4.7
Range		0.73	0.30	3.2	2.2
Std. dev.		0.25	0.12	1.2	0.8

Suggests that if the models were improved to simulate the present-day cloud regimes more realistically, the range of climate sensitivity is likely to be reduced.

The method provides a metric which:

- Is demonstrated to be relevant to the climate sensitivity
- Implicitly up-weights those regimes which the GCMs suggest are most important for the global cloud radiative response.
- When decomposed, provides information to model developers regarding which regimes require attention.

Conclusions

- Cloud regimes offer a useful framework in which to evaluate a GCM and analyse its climate change response.
- A significant contribution to the variation in the global cloud radiative response amongst the GCMs analysed here can be associated with differences in the present-day simulation (particularly the frequency of tropical stratocumulus and extra-tropical frontal cloud). (Data from more models are required to check how robust this is.)
- There appears to be potential to reduce the range of climate sensitivity between GCMs if the present-day cloud regimes were simulated more consistently.
- The method provides a metric which is demonstrated to be relevant to the climate change response, so might be considered a useful addition to a basket of measures of GCM performance.
- Currently developing a method for clustering onto the observed regimes in order to put into the ISCCP simulator (with Mark Webb) – for application to large ensembles.